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# TECHNICAL MEMORANDUM

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SUBJECT: Rationale and Summary for using World Health Organization Toxicity Equivalency Approach, Santa Susana Field Laboratory, Ventura County, California

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This paper provides technical information regarding dioxins and furans (dioxins) and polyaromatic hydrocarbons (PAHs) that the Department of Toxic Substances Control (DTSC) considered during Look-Up Table (LUT) value development for these chemical classes.

DTSC evaluated two classes of chemicals, dioxins and PAHs. Each class is comprised of many structurally-related chemicals (for dioxin/furans, these are known as “congeners”) that typically occur together in mixtures of variable composition. The congeners have a wide range in relative toxicity, but act through a common cellular mechanism to cause cancer. PAHs also appear to act through a common mechanism to cause cancer, although this mechanism differs from that of dioxins. Because of these characteristics, these chemical classes are typically regulated by environmental agencies as a 'group' with cleanup standards based on chemical mixtures instead of regulating according to each individual dioxin or PAH in a sample.

Since the early 1990’s, the World Health Organization (WHO) has organized expert meetings with the objective to harmonize the toxic equivalency factors (TEFs) for dioxin and dioxin-like compounds on the international level, thereby giving recommendations to national regulatory authorities. The WHO approach uses congener-specific TEF’s that enable development of a single toxicity equivalent (TEQ) value for all dioxins in a sample.

As part of the evaluation, DTSC has concluded that the Santa Susana Field Laboratory (SSFL) Look-Up Table values for carcinogenic dioxin/furans will be based on the World Health Organization - toxic equivalency (WHO-TEQ) approach. In addition, a similar approach, referred to as the Benzo(a)pyrene equivalent (BaPe), will be used for carcinogenic PAHs.

**Where the WHO-TEQ approach is used**

The WHO-TEQ approach is used on all DTSC and USEPA sites where dioxins and furans are being evaluated. In addition, the WHO-TEQ approach is in DTSC and USEPA guidance (see links below). The WHO-TEQ approach is so commonly used and accepted that at this point most toxicologist would agree that a justification would be required for not using it in a standard evaluation process.

USEPA recommended TEFs can be found in guidance: http://www.epa.gov/raf/files/tefs-for-dioxin-epa-00-r-10-005-final.pdf

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DTSC dioxin human health guidance is at:
http://www.dtsc.ca.gov/AssessingRisk/upload/HHRA_Note2_dioxin-2.pdf

**WHO-TEF Evaluations**
WHO-TEF evaluations were conducted in 1993, 1997 and 2005. The 1993 evaluations resulted in human and mammalian WHO TEFs for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs.) WHO also recommended a TEF value for several polychlorinated biphenyls (PCBs- Ahlborg *et al*., 1994). A WHO TEF (re)evaluation was again done in 1997, leading to revision of several mammalian TEF values of important congeners and withdrawal of the di-ortho-PCBs from the TEF concept for dioxin-like compounds. In addition, the first WHO TEF values for birds and fish were proposed (Van den Berg *et al*., 1998). To support this meeting, the Karolinska Institutet in Stockholm (Sweden) prepared a relative potency value database with results from all studies known at that time. The results were used to determine the WHO 1998 TEF values. In June 2005, WHO - International Programme on Chemical Safety expert meeting was held in Geneva during which TEF values for dioxin-like compounds, including some PCBs, were reevaluated (Van Den Berg *et al*., 2006.) Table 1 provides a list of the dioxin-furan congeners and associated TEF values.

**Why the WHO-TEQ approach is used**
Hundreds of congeners are formed during synthetic processes such as combustion and certain industrial activities. Exposure either through food or the environment results in the uptake of a large number of these compounds. Assessment of these compounds involves a complex mixture of PCDD, PCDF, and PCB compounds that share a common toxicological mechanism of action.

The TEQ is a single number that represents the mixture of dioxins- furans in terms of the most toxic form of dioxin; 2,3,7,8-TCDD. DTSC believes the WHO-TEQ approach is health-protective and a reasonable approach to address dioxins-furans at SSFL.

**Summary of toxicity equivalent factor (TEF) Rationale for Chemical Look-Up Table**
The following three primary technical points summarize DTSC's consideration for using toxicity equivalent factors to establish Look-Up Table values for dioxins-furans (dioxins) and polyaromatic hydrocarbons (PAHs):

- The WHO-TEF approach was applied to DTSC's Chemical Background Study results to establish a single Look-Up Table background TEQ value. That TEQ value will be used to compare to on-site, sample-specific results. In compliance with the AOCs, the TEF approach does not allow for combining or averaging of samples.
- The WHO-TEF approach addresses the high variability in the dioxins/PAHs in background data. The same variability occurs on-site. If this variability is not addressed, it will lead to an un-implementable cleanup by trying to cleanup background levels (i.e., high false-positives). Without the WHO-TEF approach, approximately 9-10% of the chemical background area samples exceeded the Look-Up Table dioxin/furan values, based on dioxin/furans alone.

Use of TEFs is a standardized methodology for regulatory evaluation of dioxins, and is used throughout California and by USEPA nationwide. Since applied as 'standard practice' by DTSC, the use of TEFs is a feasible and implementable approach for the AOC-based cleanup. The TEF provides a standardized parameter for evaluation.

Related information that DTSC considered in developing the Look-Up table TEQ value is further described below.

**I. Administrative Orders on Consent (AOC)**

The use of dioxin and PAH TEQs when evaluating on-site sampling results for a cleanup determination is compliant with the AOCs because the TEQ approach is a point-by-point comparison of an 'on-site' result to 'background' results.

**Summary of TEQ Rationale for Inclusion in Look-Up Table**

a. AOC Section 2.1 - "The cleanup of soils at the Site shall result in the end state of the Site after cleanup being consistent with "background" (i.e., at the completion of cleanup, no contaminants shall remain in the soil above local background levels ... )."

- Background is the cleanup standard, and background dioxin and PAH soil results expressed as TEQs represent background.

b. AIP Page 2 - "Residual concentrations 'not to exceed' local background concentrations i.e., if during site survey efforts or during confirmatory sampling the level of any constituent detected in a soil sample is above local background levels, step-outs will be taken to delineate the contamination and removed; soil above local background will not be averaged with other soil."

- Each TEQ is a sample-specific summation of TEFs from a single sample, not an 'averaged' result of multiple chemicals within a sample, or between multiple samples. Averages are calculated by summing the concentrations of a single chemical from more than one sample and dividing that sum by the number of samples included. Averaging is not done in the TEQ approach.

- Comparison of an individual on-site TEQ result to a background TEQ result is compliant and consistent with the AOC/AIP 'not to exceed' approach.

c. AIP Page 2-3 - "Upon completion of the DTSC led chemical background study, a 'look-up' table of the chemical cleanup levels will be prepared, which will include both local background concentrations as well as minimum detection limits for specific contaminants whose minimum detection limits exceed local background concentrations."

- Background TEQ values are calculated results using local background concentrations as determined by DTSC.

**II. Variability**

The variability of dioxins, furans and PAH results are high in the background dataset. If a dioxin congener-to-congener and PAH chemical-to-chemical approach is used, there will be a larger number of false positive decision errors. This would potentially lead to an unimplementable and un-necessary (cleanup of clean soil) cleanup.

**Summary of TEQ Rationale for Inclusion in Look-Up Table**

*a.* A TEQ approach:

- Uses a single comparison standard representing local background.
- Reduces the effect of variability on identification of site-related contamination (minimizes false-positive decision errors.)
- Provides for an implementable and AOC consistent cleanup.

b. Dioxins/furans are mixtures of chemicals, with relative proportions of the individual chemicals dependent on the source area, including vegetation type and density, soil composition, drainages and topography, etc.

c. "Variability" means that dioxin congener and PAH concentrations in the background dataset vary considerably from the USL95 BTV. This is demonstrated by:

i. USL95 BTV values above the maximum result without outliers, and
ii. The number and magnitude of outliers identified for each constituent (Figures 1a-d and Table 2).

d. Since background variability is high, similar background variability was expected to be high and a data evaluation reflects that is the case. The effect of the variability could be demonstrated by comparing the number of congener/PAH exceedances versus TEQ exceedances relative to the chemical background area. That evaluation showed

i. Variability in the background dataset increases the chance that any individual congener or PAH will exceed a chemical-specific Look-Up Table value.

ii. High variability in the on-site and background dioxin and PAH datasets results in increased false-positive cleanup decision errors, and leads to an un-implementable and un-necessary cleanup by attempting to remediate background concentrations (i.e., where do you stop digging?). Such a result provides little if any additional protection of human health, and may damage the environment.

iii. Dioxin congener distribution patterns are similar between background and on-site sample results with TEQs less than the background TEQ; however, above the background TEQ value, on-site congener distributions are different from background. This similarity supports the TEQ approach; providing a 'background' comparison consistent with the intent of the AOC.

## III. World Health Organization – TEQ approach

TEQs are the regulatory 'standard of practice' used by DTSC, EPA, and other agencies to develop cleanup standards for these chemicals within California, across the nation, and around the world.

**Summary of TEQ Rationale for Inclusion in Look-Up Table**

a. TEQs are widely used by regulators to establish cleanup standards because they:

- Provide a single parameter for comparison and cleanup planning
- Represent a sum of the individual results relative to the most toxic compound (2,3,7,8-TCDD or Benzo(a)Pyrene)
- Reduce the effect of concentration variability among individual chemicals.

b. TEQs use the relative toxicity of the individual congeners via a common mechanism to normalize concentration data in both the background and on-site datasets, resulting in a 'like to like' comparison. TEQs are a summation of concentrations that accounts for toxicity, and is not a risk assessment (Table 1).

c. DTSC guidance, "Remedial Goals for Dioxins and Dioxin-Like Compounds for Consideration at California Hazardous Waste Sites," specifies the use of TEQs for setting cleanup goals for the protection of human health. (This is a risk assessment guidance document, but application of toxicity factors and TEQs are not limited to risk assessment.)

d. Relative toxicities for the chemicals are set by the World Health Organization. EPA and DTSC have adopted these values in calculating TEQs.

e. DTSC-led site cleanup examples where TEQs have been used for cleanup include: McClellan AFB, Travis AFB, George AFB, and the Alhambra Southern California Edison site.

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Tables

1 Dioxin-furan World Health Organization Toxicity Equivalency Factors
2 Variability in Dioxin and PAH Background Concentrations

Figures

1a-d Background Chemical Scatter Plots

REFERENCES

Ahlborg, et al. 1994.
Van den Berg, et al, 1998.
Van den Berg, et al. 2006.

**Table 1**

**Dioxins-Furans**
**World Health Organization**
**Toxicity-Equivalency Factors**

| Dioxin-Furan | Full Name | WHO TEF |
|---|---|---|
| 1,2,3,4,6,7,8-HpCDD | 1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin | 0.01 |
| 1,2,3,4,6,7,8-HpCDF | 1,2,3,4,6,7,8-Heptachlorodibenzofuran | 0.01 |
| 1,2,3,4,7,8,9-HpCDF | 1,2,3,4,7,8,9-Heptachlorodibenzofuran | 0.01 |
| 1,2,3,4,7,8-HxCDD | 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin | 0.1 |
| 1,2,3,4,7,8-HxCDF | 1,2,3,4,7,8-Hexachlorodibenzofuran | 0.1 |
| 1,2,3,6,7,8-HxCDD | 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin | 0.1 |
| 1,2,3,6,7,8-HxCDF | 1,2,3,6,7,8-Hexachlorodibenzofuran | 0.1 |
| 1,2,3,7,8,9-HxCDD | 1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin | 0.1 |
| 1,2,3,7,8,9-HxCDF | 1,2,3,7,8,9-Hexachlorodibenzofuran | 0.1 |
| 1,2,3,7,8-PeCDD | 1,2,3,7,8-Pentachlorodibenzo-p-dioxin | 1 |
| 1,2,3,7,8-PeCDF | 1,2,3,7,8-Pentachlorodibenzofuran | 0.03 |
| 2,3,4,6,7,8-HxCDF | 2,3,4,6,7,8-Hexachlorodibenzofuran | 0.1 |
| 2,3,4,7,8-PeCDF | 2,3,4,7,8-Pentachlorodibenzofuran | 0.3 |
| 2,3,7,8-TCDD | 2,3,7,8-tetrachlorodibenzo-p-dioxin | 1 |
| 2,3,7,8-TCDF | 2,3,7,8-Tetrachlorodibenzofuran | 0.1 |
| OCDD | Octachlorodibenzo-p-dioxin | 0.0003 |
| OCDF | Octachlorodibenzofuran | 0.0003 |

# Table 2

## Variability in Dioxin and PAH Background Concentrations Compared to the BTV

| | Number of Outliers Identified | 2012 USL95 Combined Strata BTV (mg/kg) | Max 2012 BG Including Outliers (mg/kg) | Max 2012 BG w/o Outliers (mg/kg) | Ratio of Max 2012 w Outliers/BTV | Ratio of Max 2012 w/o Outliers/BTV | Ratio of Ratios (ratio w/ outliers to ratio w/o) |
|---|---|---|---|---|---|---|---|
| **PCDD/PCDFs** | | | | | | | |
| 1,2,3,4,6,7,8-HpCDD | 1 | 0.00000352 | 0.0000068 | 0.0000035 | 1.93 | 0.99 | 1.9 |
| 1,2,3,4,6,7,8-HpCDF | 1 | 0.000000941 | 0.0000018 | 0.00000092 | 1.91 | 0.98 | 2.0 |
| 1,2,3,4,7,8,9-HpCDF | 1 | 0.0000000886 | 0.00000017 | 0.00000009 | 1.92 | 1.02 | 1.9 |
| 1,2,3,4,7,8-HxCDD | 2 | 0.000000102 | 0.0000002 | 0.00000009 | 1.96 | 0.88 | 2.2 |
| 1,2,3,4,7,8-HxCDF | 1 | 0.00000017 | 0.00000035 | 0.00000018 | 2.06 | 1.06 | 1.9 |
| 1,2,3,6,7,8-HxCDD | 0 | 0.000001082 | 0.0000013 | 0.0000013 | 1.20 | 1.20 | 1.0 |
| 1,2,3,6,7,8-HxCDF | 1 | 0.000000233 | 0.00000088 | 0.0000004 | 3.78 | 1.72 | 2.2 |
| 1,2,3,7,8,9-HxCDD | 0 | 0.000001475 | 0.000002 | 0.000002 | 1.36 | 1.36 | 1.0 |
| 1,2,3,7,8,9-HxCDF | 1 | 0.000001489 | 0.0000021 | 0.0000016 | 1.41 | 1.07 | 1.3 |
| 1,2,3,7,8-PeCDD | 3 | 0.000000138 | 0.00000033 | 0.00000013 | 2.39 | 0.94 | 2.5 |
| 1,2,3,7,8-PeCDF | 1 | 0.000000221 | 0.00000029 | 0.00000019 | 1.31 | 0.86 | 1.5 |
| 2,3,4,6,7,8-HxCDF | 1 | 0.000000244 | 0.00000058 | 0.00000026 | 2.38 | 1.07 | 2.2 |
| 2,3,4,7,8-PeCDF | 1 | 0.000000304 | 0.00000053 | 0.00000033 | 1.74 | 1.09 | 1.6 |
| 2,3,7,8-TCDD | 1 | 0.0000000358 | 0.00000014 | 0.00000006 | 3.91 | 1.68 | 2.3 |
| 2,3,7,8-TCDF | 1 | 0.000000397 | 0.00000062 | 0.00000039 | 1.56 | 0.98 | 1.6 |
| OCDD | 5 | 0.0000231 | 0.00014 | 0.000023 | 6.06 | 1.00 | 6.1 |
| OCDF | 1 | 0.000001626 | 0.0000029 | 0.0000016 | 1.78 | 0.98 | 1.8 |
| **Polynuclear Aromatic Hydrocarbons (PAH)** | | | | | | | |
| Benzo(a)anthracene | 4 | 0.001566 | 0.025 | 0.0027 | 15.96 | 1.72 | 9.3 |
| Benzo(a)pyrene | 1 | 0.0023 | 0.046 | 0.005 | 20.00 | 2.17 | 9.2 |
| Benzo(b)fluoranthene | 0 | 0.005015 | 0.012 | 0.0029 | 2.39 | 0.58 | 4.1 |
| Benzo(k)fluoranthene | 2 | 0.00529 | 0.019 | 0.007 | 3.59 | 1.32 | 2.7 |
| Chrysene | 3 | 0.003544 | 0.041 | 0.0057 | 11.57 | 1.61 | 7.2 |
| Dibenzo(a,h)anthracene | 0 | 0.00123 | 0.0023 | 0.0023 | 1.87 | 1.87 | 1.0 |
| Indeno(1,2,3-cd)pyrene | 3 | 0.000835 | 0.0042 | 0.00096 | 5.03 | 1.15 | 4.4 |

ratio >5
ratio > 1, <5 (10% difference not included)

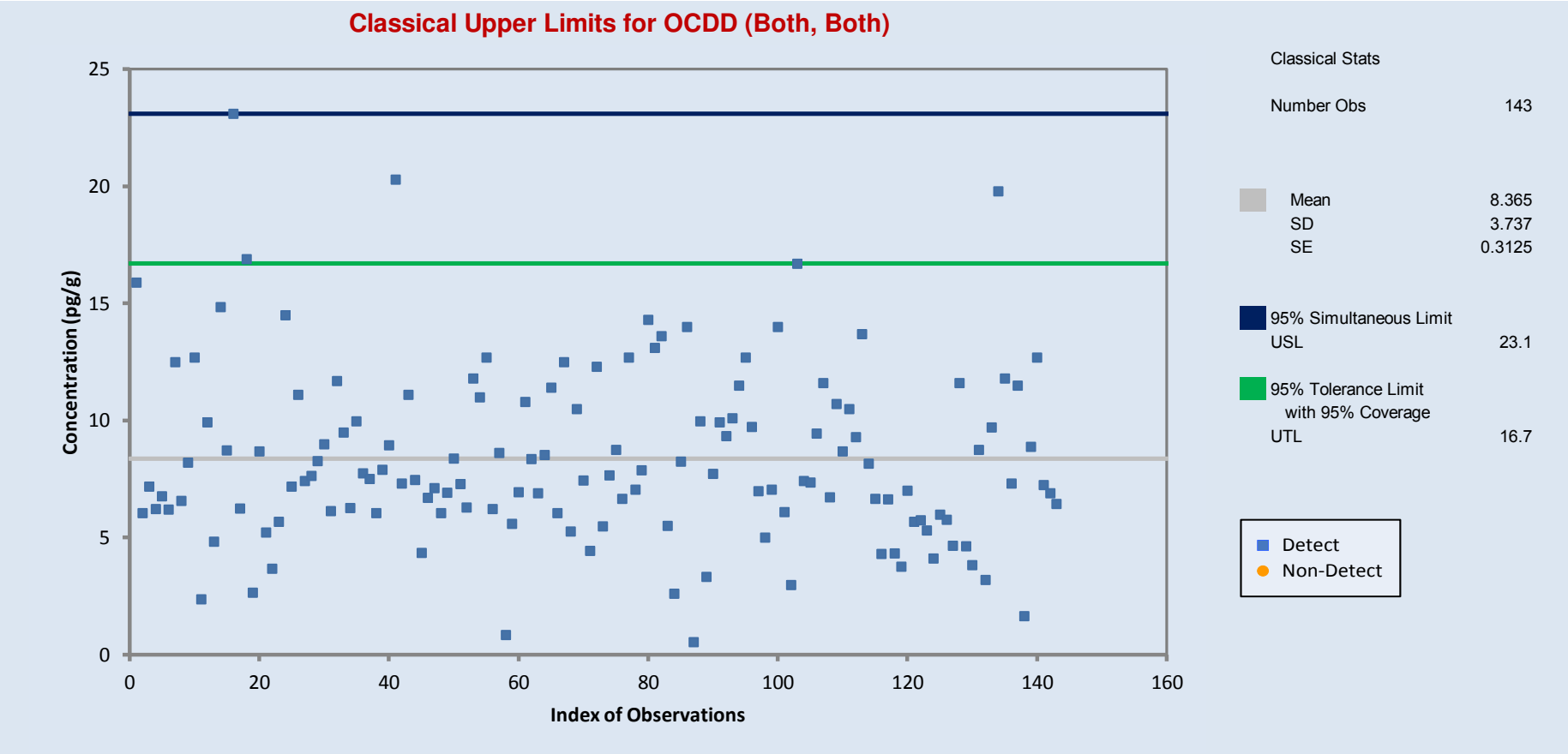
Ratio values above 1 indicate variability in the background dataset compared to BTV.
The higher the ratio value above 1, the higher the varibility observed.

Highest variability observed if outliers included. This ratio calculated since outliers represent background and an upper limit to the range of naturally occuring concentrations.

The "ratio of the ratio" indicates the magnitude of varibaility possible for each constituent. Almost every individual chemical displays variability compared to the BTV. A ratio of 1.0 incicates no outliers were identified for that chemical.

PAHs exhibit higher varibility than dioxins. The PAHs shown are only those included in the TEQ calculation. Other PAHs exhibit a similar range of variability but these chemicals will be evaluated on an individual basis.

Figure 1a

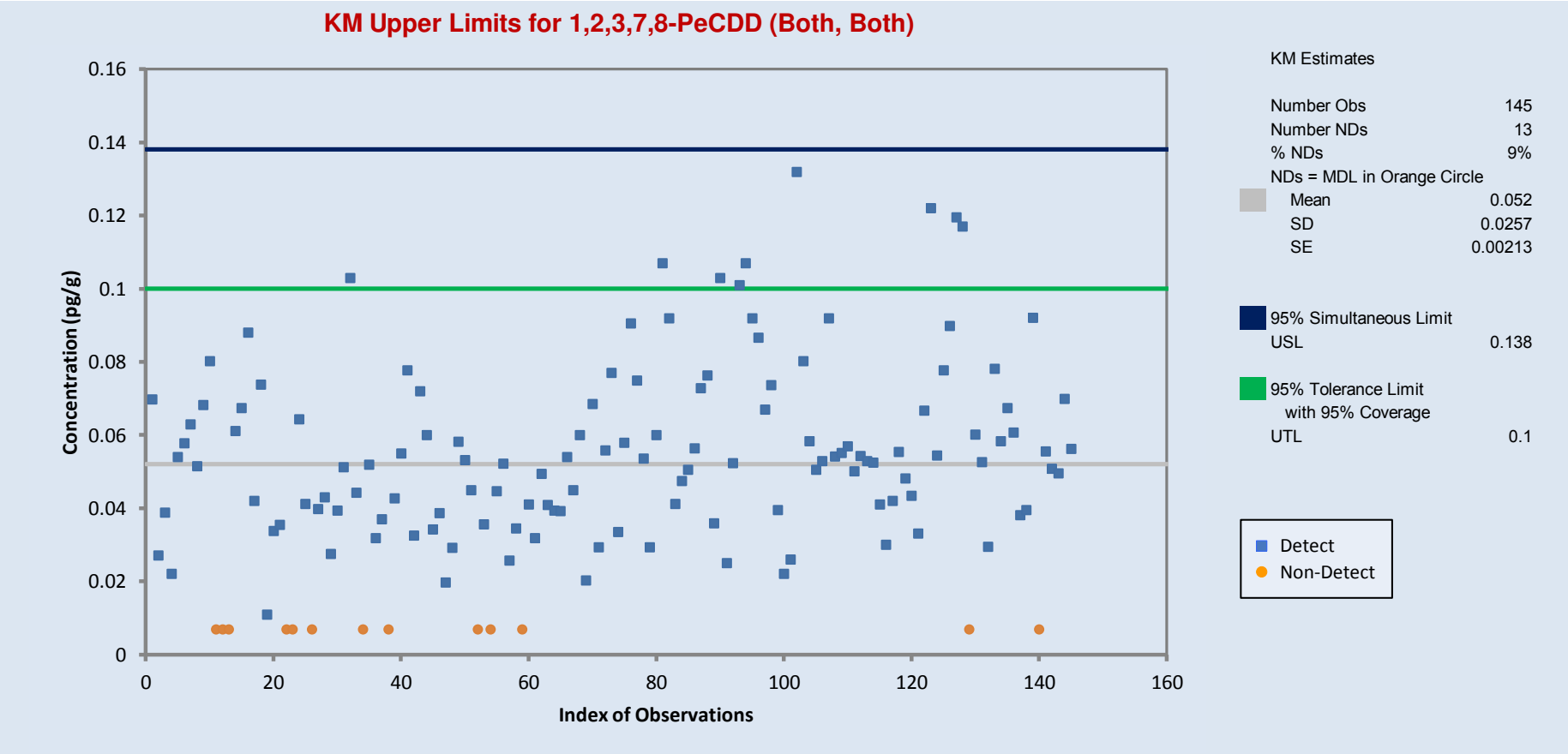



Variability within the background dataset is expected to also occur in on-site samples.

These plots illustrate that background is variable and a range of background values exists. The USL95 BTV statistically approximates the maximum. For OCDD, the USL95 BTV = MAX
5 outliers were identified, ranging up to 140 on this scale (~6X higher).

Source: DTSC Chemical Soil Background Study Report (2012)

Figure 1b

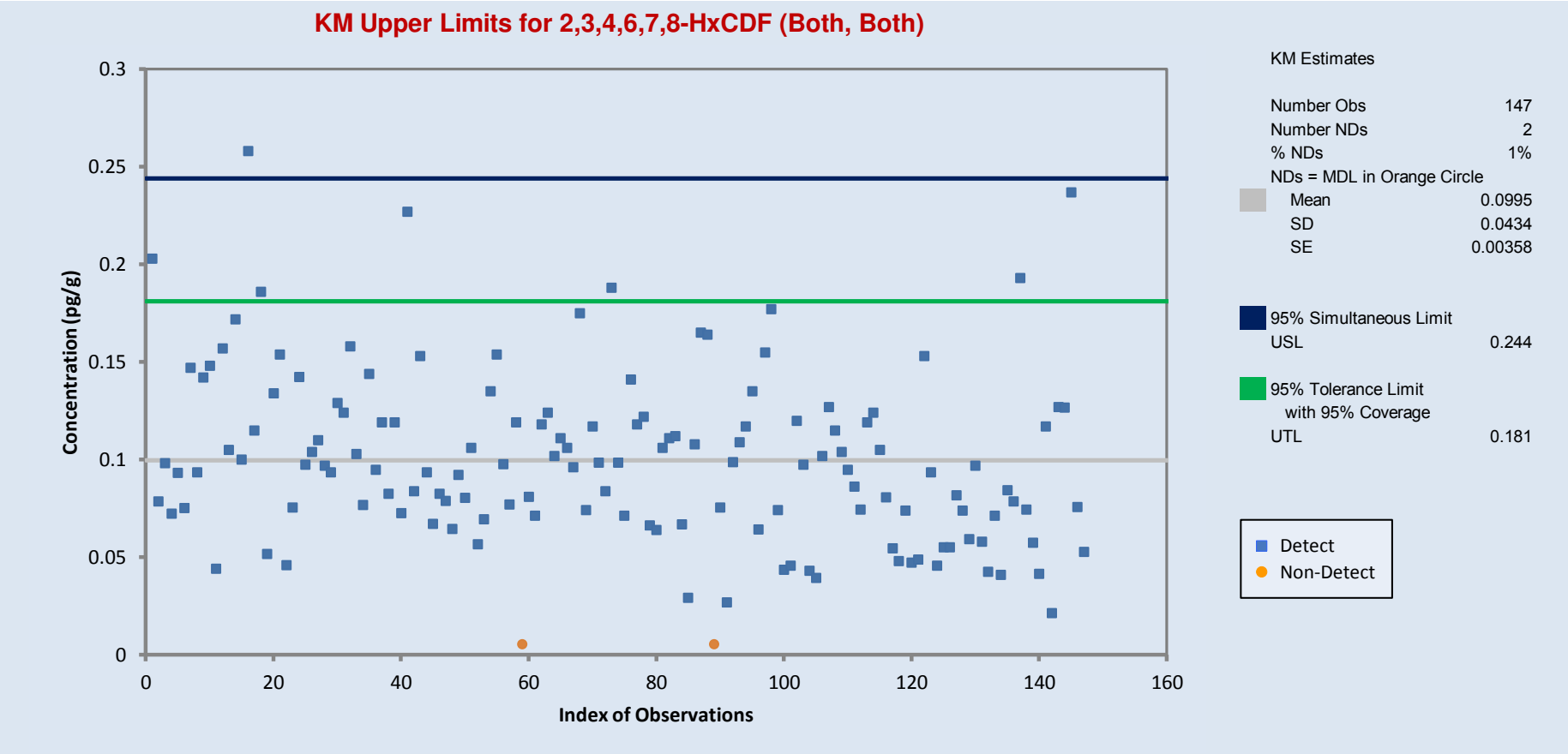



Variability within the background dataset is expected to also occur in on-site samples.

These plots illustrate that background is variable and a range of background values exists. The USL95 BTV statistically approximates the maximum. For 1,2,3,7,8-PeCDD, the USL95 BTV > MAX 3 outliers were identified, ranging up to 0.33 on this scale (~2.4 X higher).

Source: DTSC Chemical Soil Background Study Report (2012)

Figure 1c

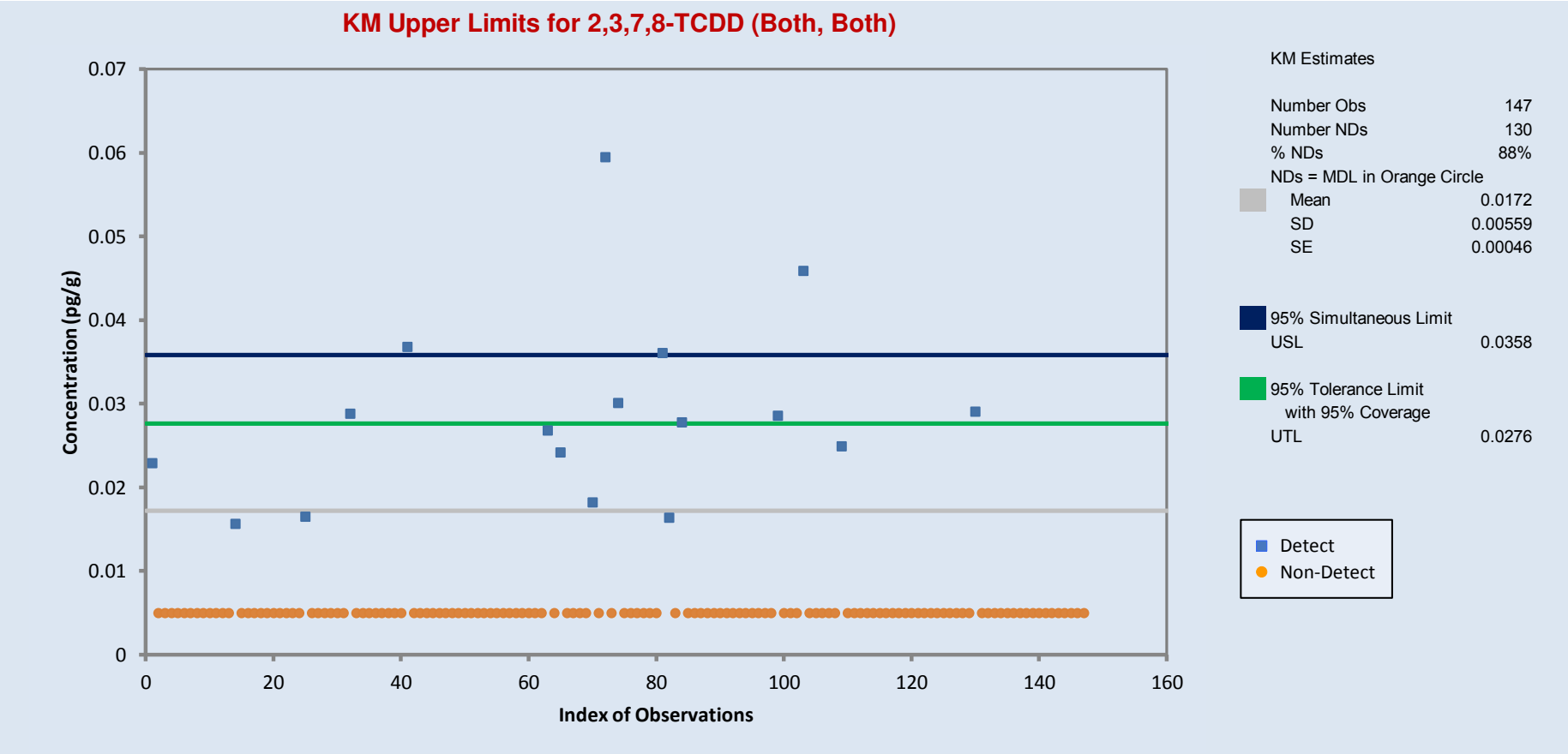



Variability within the background dataset is also expected to occur in on-site samples.

These plots illustrate that background is variable and a range of background values exists. The USL95 BTV statistically approximates the maximum.
For 2,3,4,6,7,8-HxCDF, the USL95 < MAX
1 outlier was identified, ranging up to 0.5 on this scale (~2.4X higher).

Source: DTSC Chemical Soil Background Study Report (2012)

Figure 1d




Variability within the background dataset is expected to also occur in on-site samples.

These plots illustrate that background is variable and a range of background values exists. The USL95 BTV statistically approximates the maximum.
For 2,3,7,8-TCDD, the USL95 BTV < MAX
1 outlier was identified, ranging up to 0.14 on this scale (~4X higher).

Source: DTSC Chemical Soil Background Study Report (2012)